A novel method of looking for the parity violation signal

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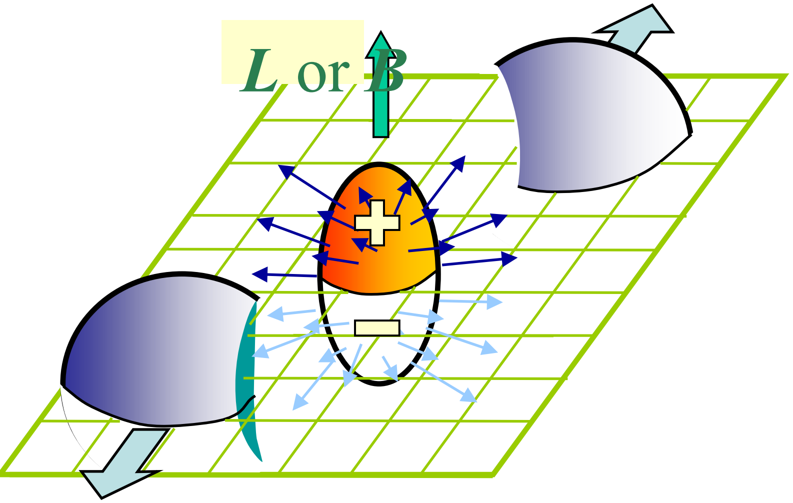
Local Parity Violation at RHIC



▪QM09 Talk by D. Kharzeev : *TIP* – Topology Induced Parity violation.

▪ *TIP* ⊕ Magnetic field ➔ Charge separation along the orbital momentum. Asymmetries ~10^{-2}, within reach of the experiment.

Azimuthal distribution w.r.t the reaction plane

$$N(\varphi) = N_0 (1+2v_2\cos(2\varphi)+2v_4\cos(4\varphi)+ 2a_1\sin(\varphi))$$

For parity violation $|a1|>0$ and has opposite sign for positive and negative charges in an event

The observable used in the standard method of analysis

$\cos(\varphi A+\varphi B-2\,\Psi_{RP})$ **is proportional to a1*a1 and so is is P-even .**

It might have contributions from physical effects not related to the strong parity violation.

Desirable to have a method which deals with an observable which is a direct measure of a1

Presented here for the first time a method involving a novel correlation C_p constructed as follows :

Define $S = \sin(\varphi_{lab} - \Psi_{RP})$

φ_{lab} = **azimuthal angle**
Ψ_{RP} = **reconstructed reaction plane**

Consider an event of multiplicity M having p positively charged hadrons and n negatively charged hadrons i.e. M = p + n

Define

$\langle S_p^{h+} \rangle$ = **average of S over the p positively charged hadrons in the event**

$\langle S_n^{h-} \rangle$ = **average of S over the n negatively charged hadrons in the event**

$\langle S_p^{h} \rangle$ = **average of S over p randomly chosen hadrons (irrespective of charge) in the same event**

$\langle S_n^{h} \rangle$ = **average of S over the remaining n hadrons in same event**

Note: Unmixed set :	**p positives**	**n negatives**
Mixed set :	**p randomly picked**	**n remaining**

The new correlation C_p is defined as

$$C_p\left(\Delta S\right) = \frac{N\left(\left\langle S_p^{h+}\right\rangle - \left\langle S_n^{h-}\right\rangle\right)}{N\left(\left\langle S_p^{h}\right\rangle - \left\langle S_n^{h}\right\rangle\right)}, \quad \Delta S = \left\langle S_p\right\rangle - \left\langle S_n\right\rangle$$

where $N\left(\left\langle S_p^{h+}\right\rangle - \left\langle S_n^{h-}\right\rangle\right)$ **and** $N\left(\left\langle S_p^{h}\right\rangle - \left\langle S_n^{h}\right\rangle\right)$ **are distributions over events**

Note :

1) **Random choice of particles removes charge correlations in the denominator of Cp**

2) **C_p is constructed entirely from a real event; hence it is pure in event class (centrality, vertex etc)**

The response of the new correlation to a parity violating signal is tested by means of a simulation done as follows :

a) Reaction plane is chosen

b) Particles are emitted with azimuthal distribution w.r.t. RP
$N(\varphi) = 1+2v_2\cos(2\varphi)+2v_4\cos(4\varphi)+ 2a_1\sin(\varphi)$

c) Neutral decay particles (e.g. Λ ,K_s^0) are emitted with respect to RP. All required data are taken from experiment.

d) Decay kinematics followed to get daughter particle directions and momenta

e) Jet particles emitted to correspond to measured jet correlations

f) Particles are passed through an acceptance filter made up from the measured singles distributions for positive and negative particles

g) A reconstructed Reaction Plane is associated with the event taking dispersion from experiment.

The simulation is tuned to reproduce experimental

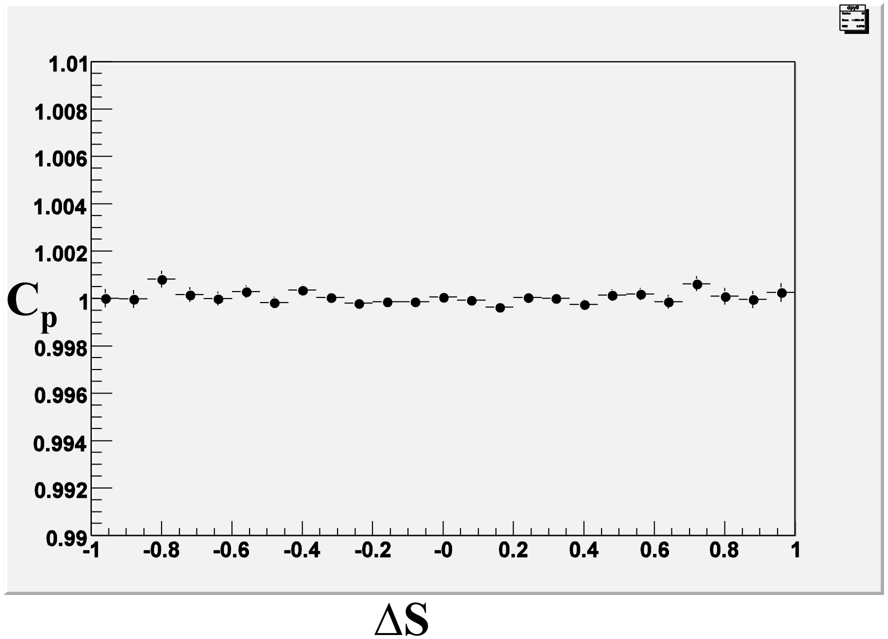
a) multiplicity distributions

b) Positive-negative azimuthal pair correlations to constrain decay contribution

c) Azimuthal distribution with respect to reconstructed Reaction Plane

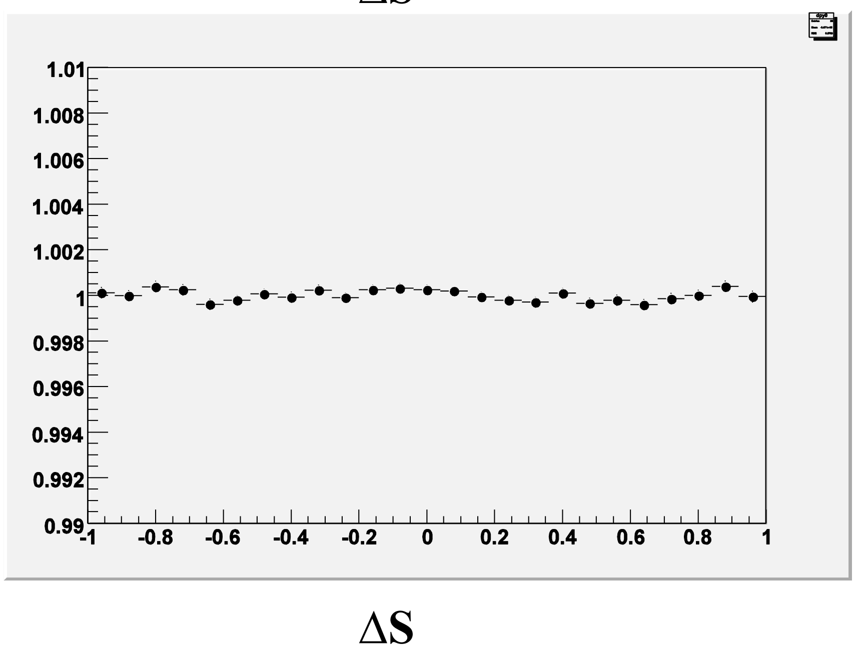
The correlation Cp is calculated for both experiment and simulation and compared for different values of the parity violating signal.

Simulation results for the form of C_p for different cases :



Flow : Yes
Parity Violating signal : none
Decay : None

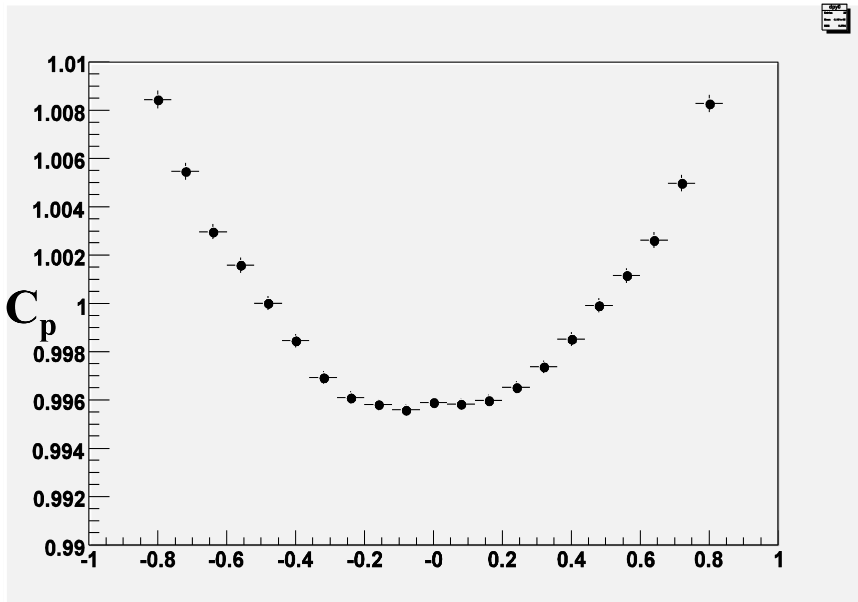
Flat response to flow



Jet : yes
Parity Violating signal : none
Decay : None

Flat response to jets

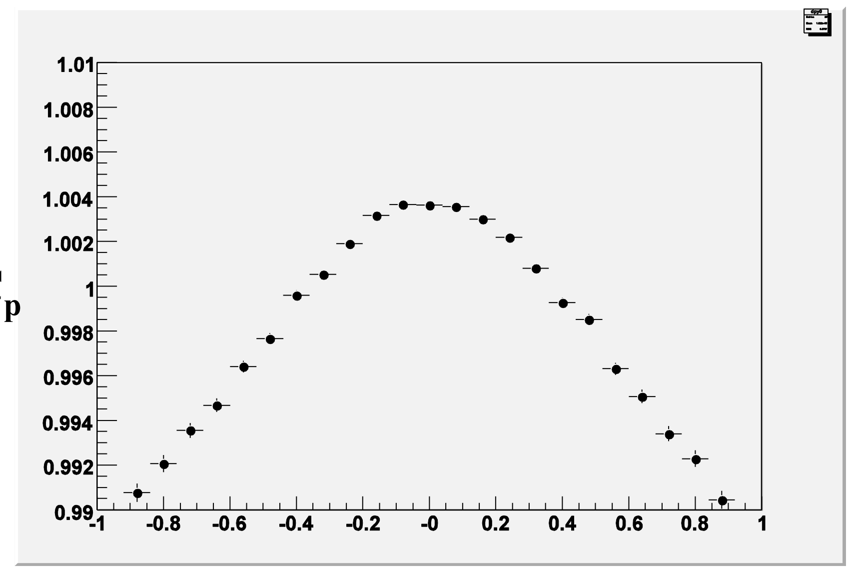
Simulation results for the form of C_p for different cases :



ΔS

Flow : Yes
Parity Violating signal: Yes
Decay : No

Concave response to parity violation



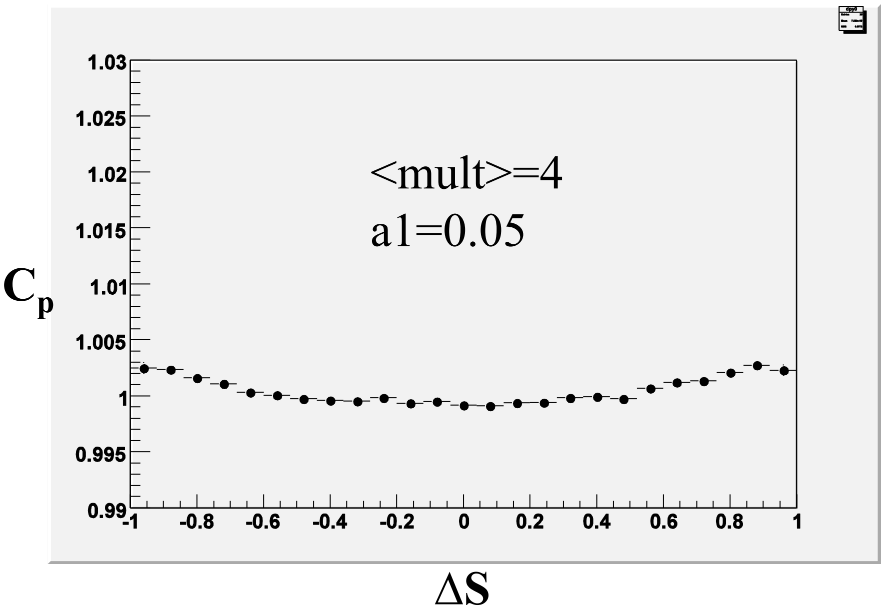
C_p

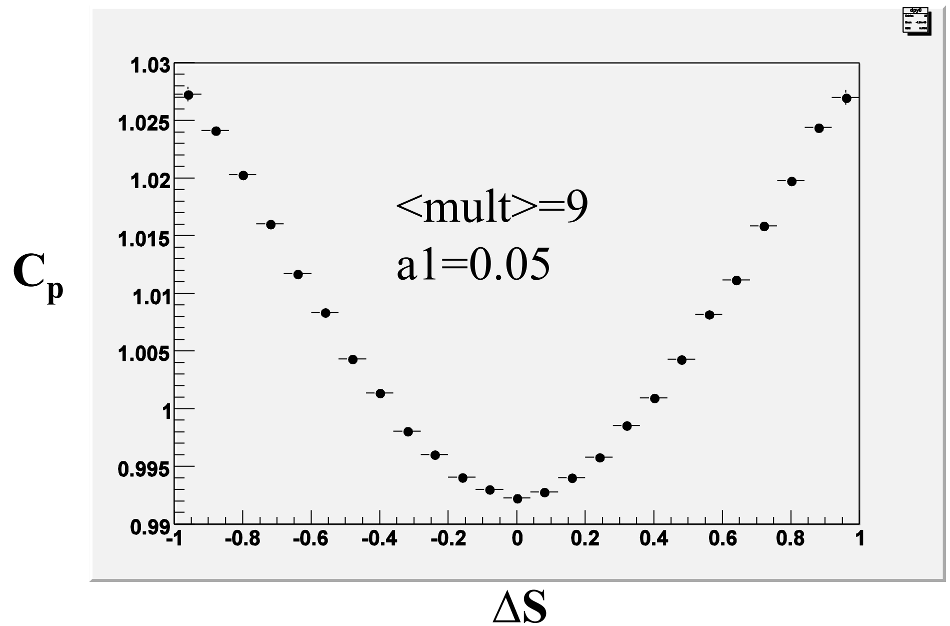
ΔS

Flow : Yes
Parity Violating signal : none
Decay : Yes

Convex response to decay

Multiplicity Dependence of C_p for fixed a_1

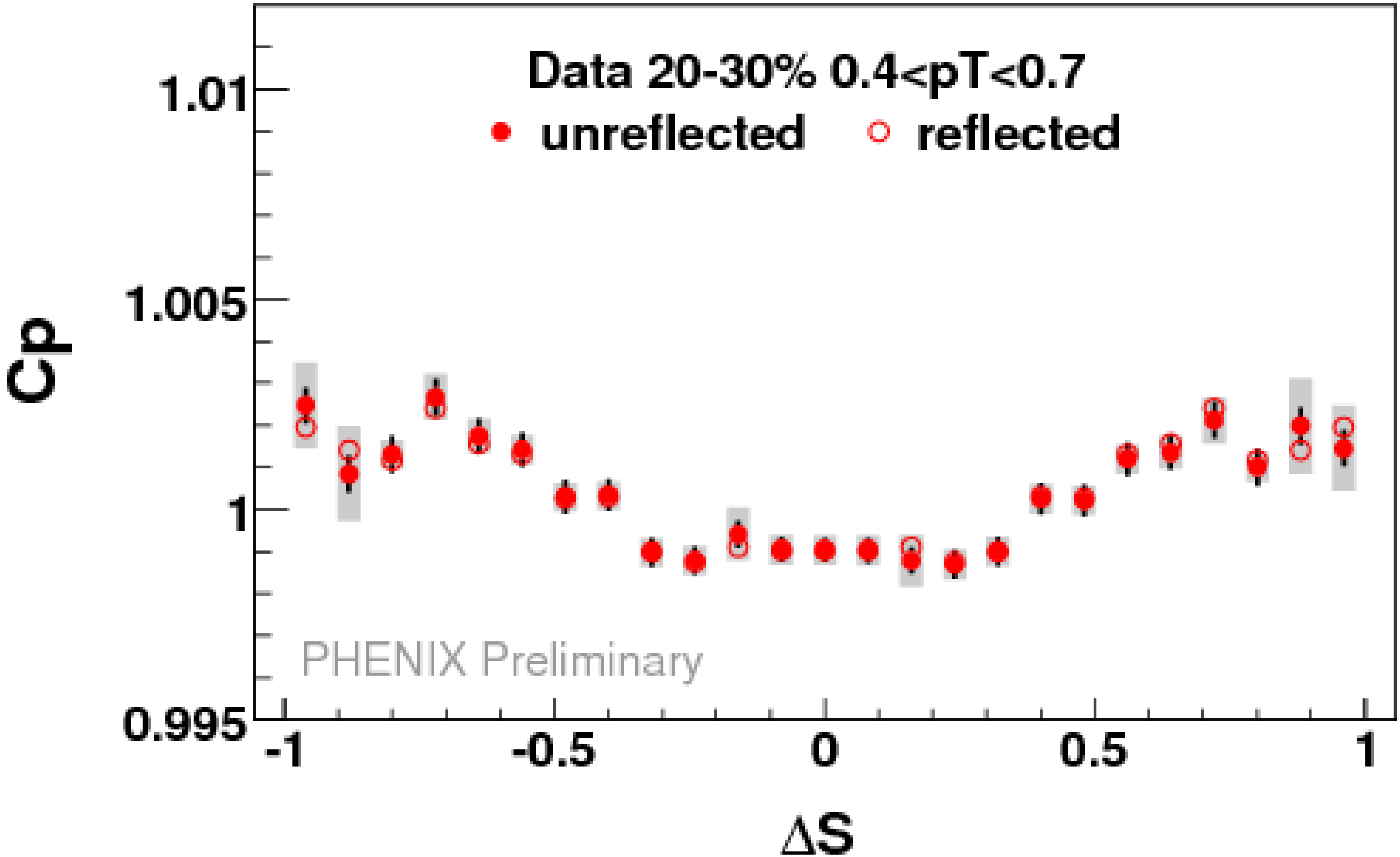




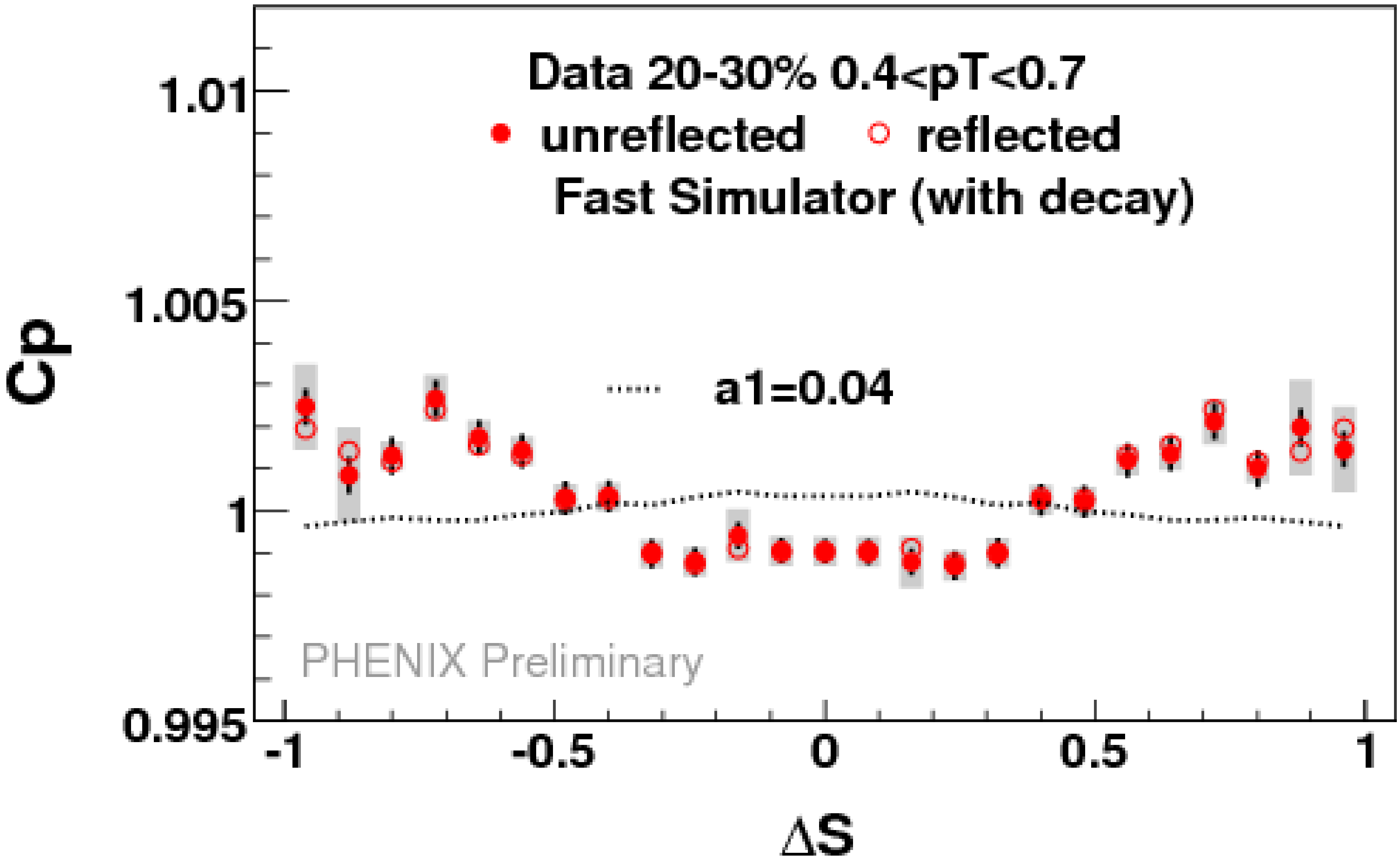
C_p strength depends on multiplicity

Now we will see comparisons of Cp from data and sims for two centralities 20-30% and 0-5% for 0.4<pT<0.7

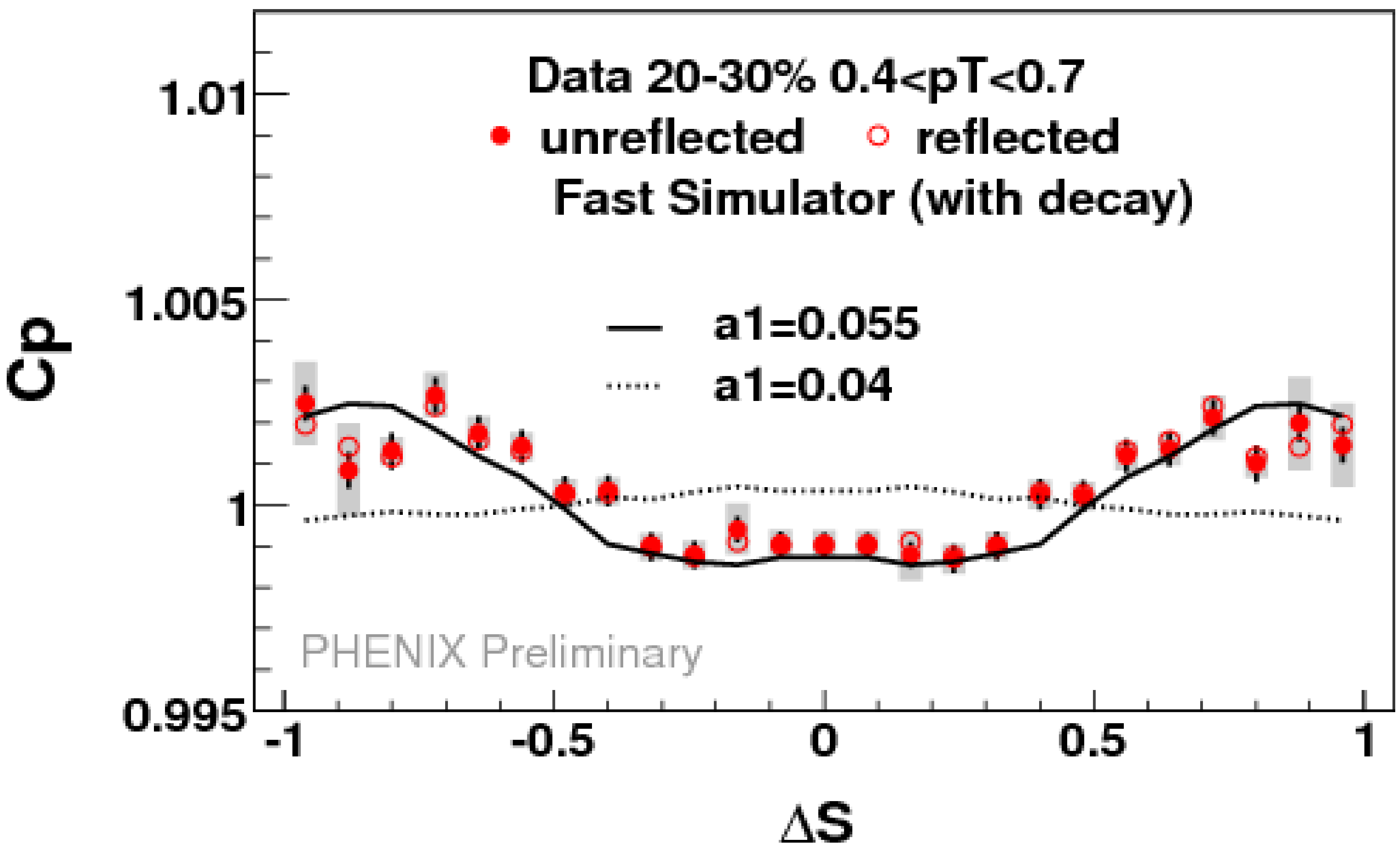
In each case the sims reproduce observed azimuthal distribution, multiplicity distribution, azimuthal distribuitions w.r.t Reaction Plane and positive-negative pair correlations.



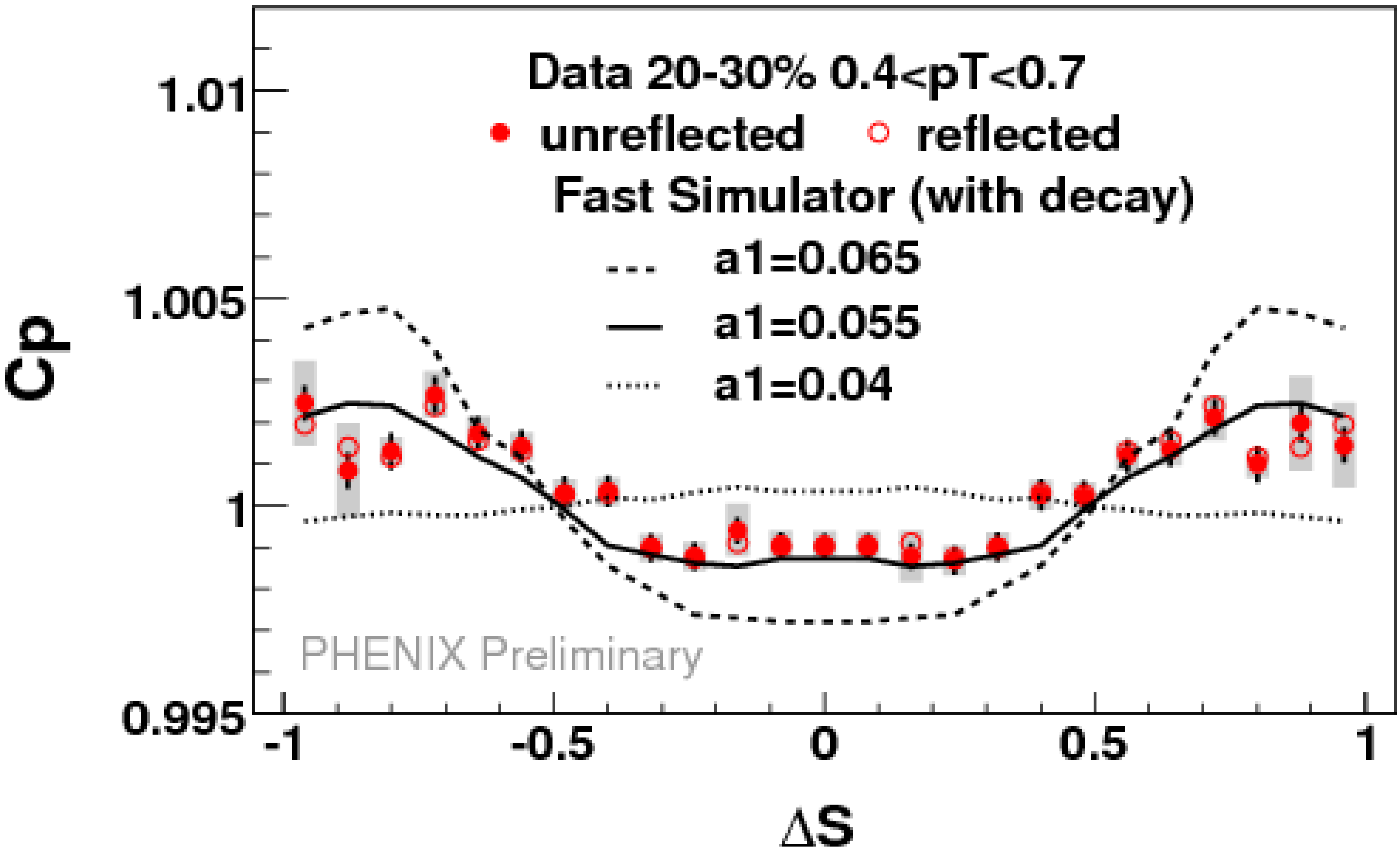
Data Cp is concave i.e. |a1|>0



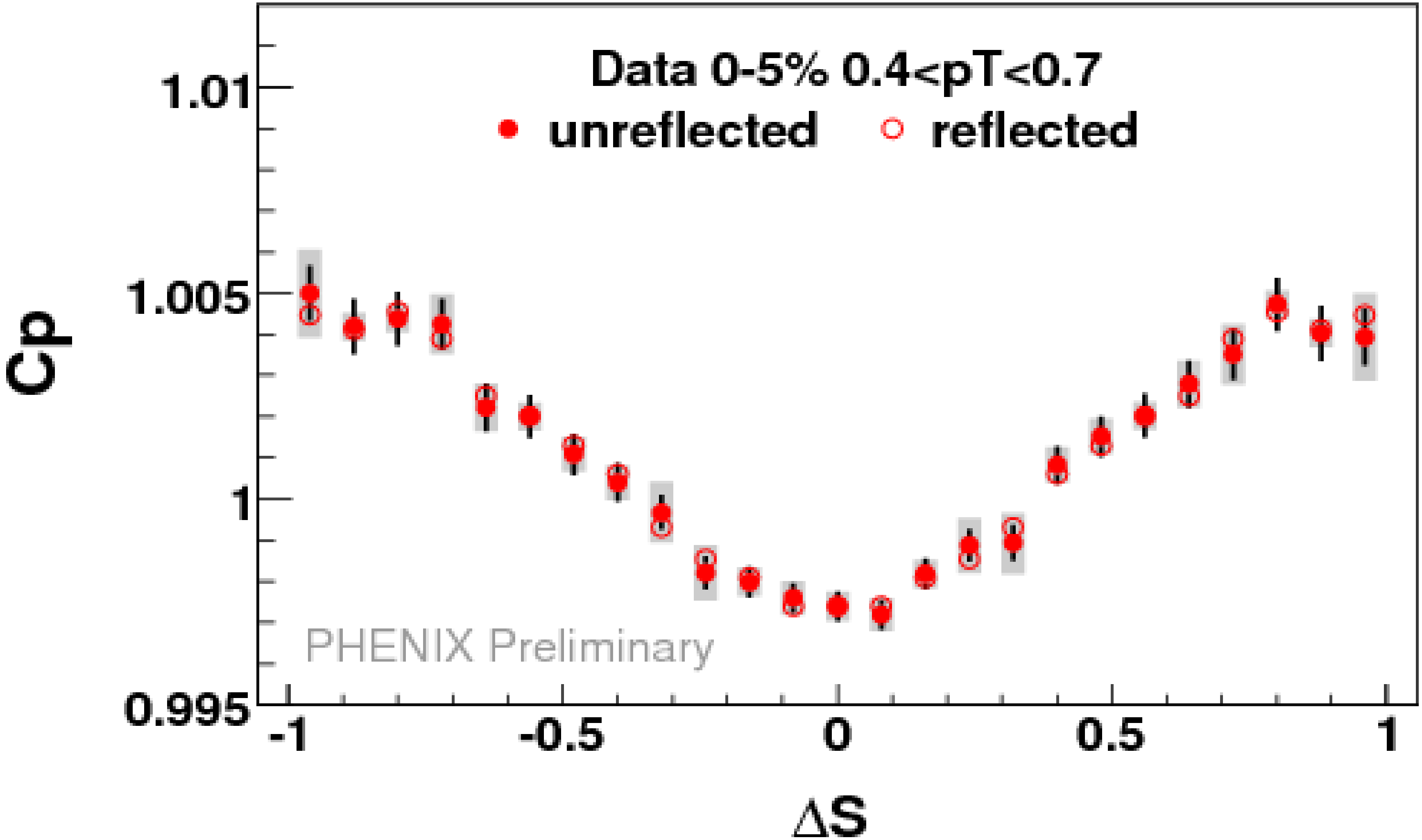
a1=0.04 sim gives convex shape



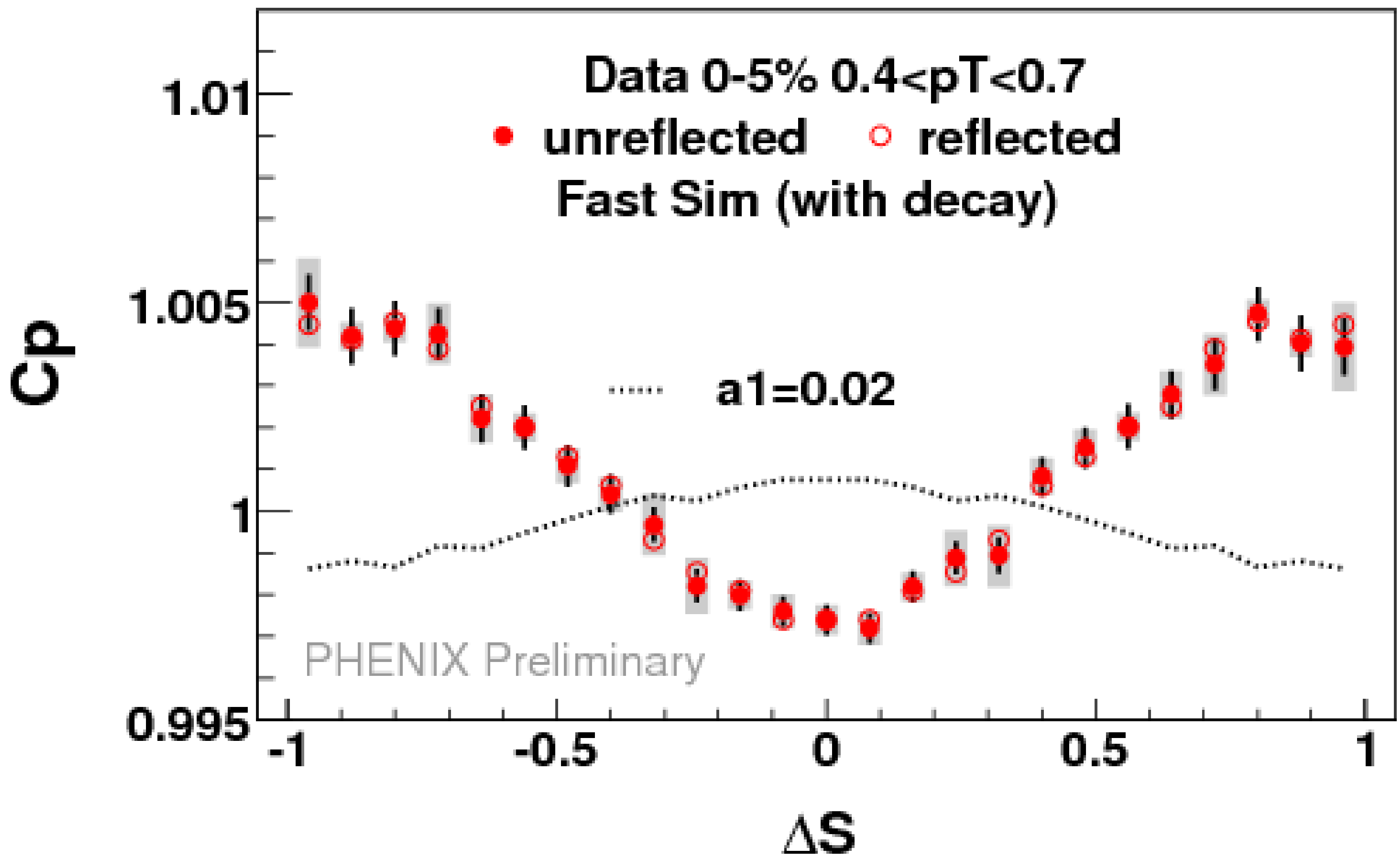
a1=0.055 sim gives concave shape close to data



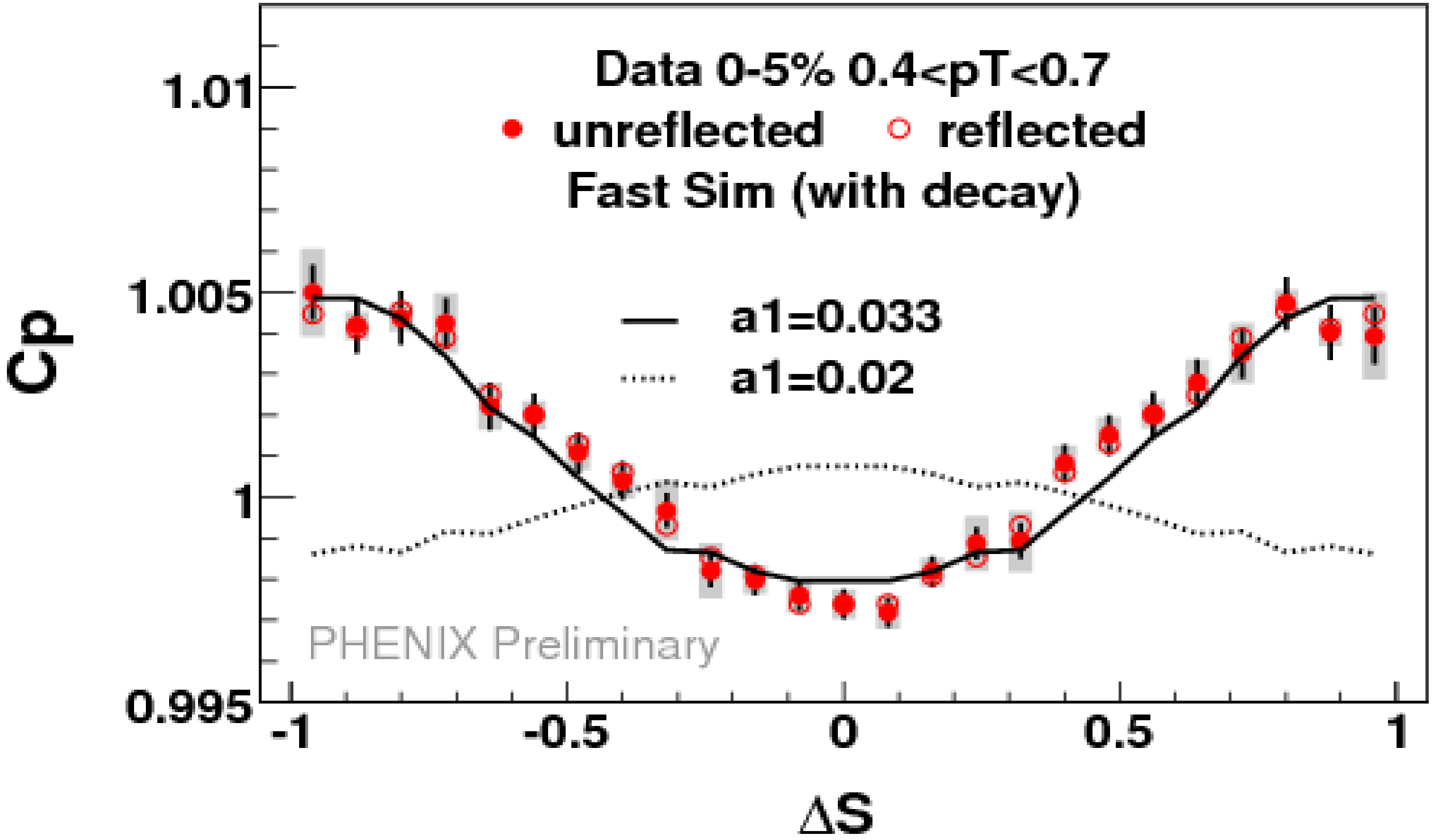
a1=0.055 sim gives concave but misses data



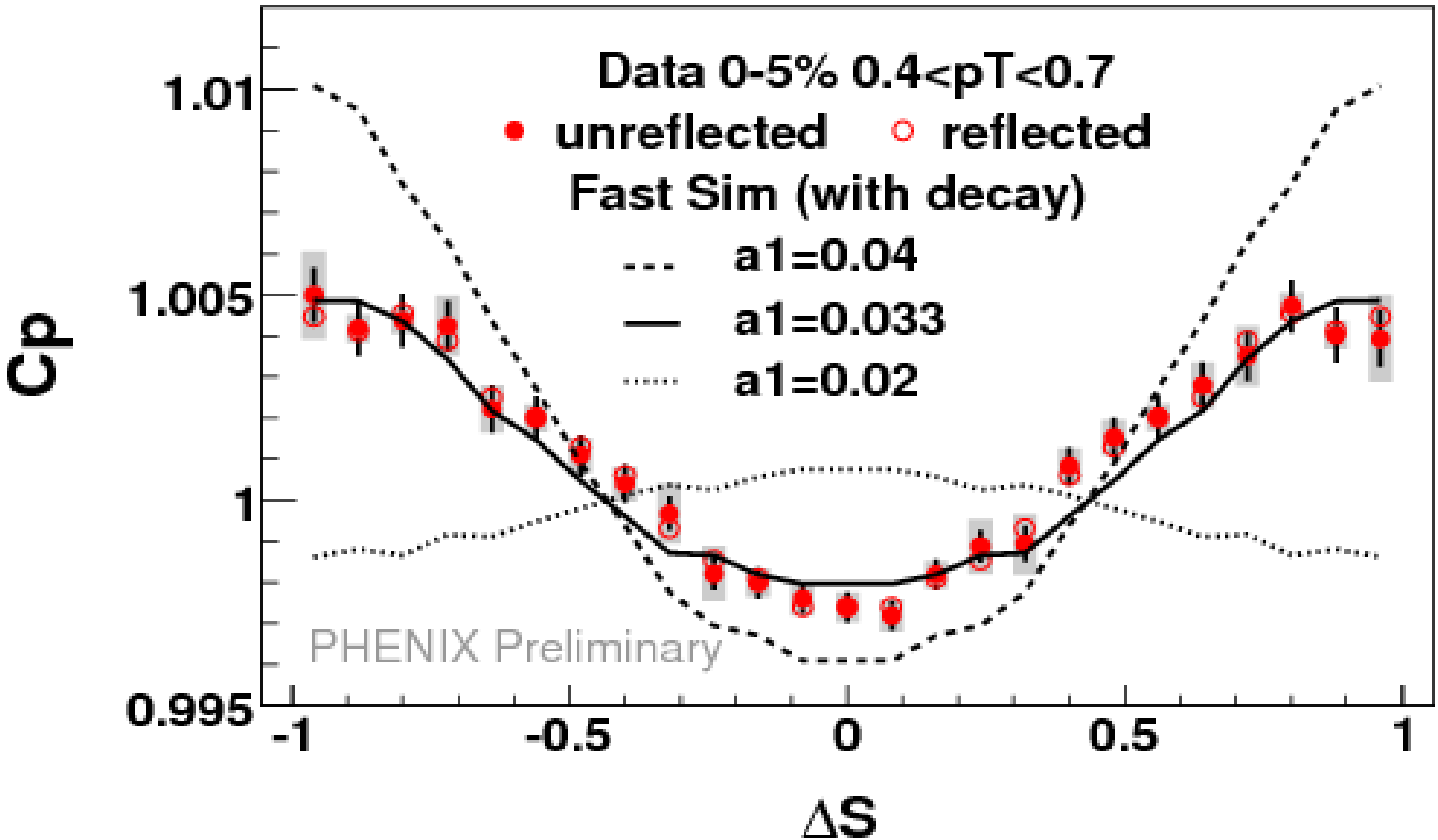
Data Cp is concave i.e. |a1|>0



a1=0.02 sim gives convex shape



a1=0.033 sim gives concave shape close to data



a1=0.04 sim gives concave but misses data

Conclusions

A new method has been formulated which measures directly the local parity violating signal "a1"

This involves the formulation of a novel correlation function C_p whose shape is concave only when there is a non-zero parity violating signal

The strength of C_p is related to the parity violating signal 'a_1'.

The observed concave shape for C_p in the data means $|a_{1|} > 0$

By making a fit to the observed Cp it is possible to constrain the allowed values of a1

The larger the detected multiplicity, the larger the sensitivity of Cp to value of a1 i.e. large acceptance is an advantage